PREDICTION OF GRINDING MACHINABILITY WHEN GRIND P20 TOOL STEEL USING TiO_2 NANOFLUID

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ABSTRACT

The surface roughness is a variable often used to describe the quality of ground surfaces as well as to evaluate the competitiveness of the overall grinding system. A grinding process was performed on the P20 tool steel by changing the grinding conditions, including the depth of cut, the grinding passes, the type of wheel, and the cutting fluid supply in the experiment. The main objective of the study is to investigate the effect of TiO_2 nanofluid on the grinding surface finish and wheel tool life. The 0.1 % volume concentration of the TiO_2 nanofluid is prepared as to compare the effectiveness with the water based coolant. The selected specimens undergo SEM to assess the surface integrity of the machined surfaces. ANN prediction models are developed from the collected data.The result showed the reduction of 20 % to 40 % surface roughness value in grinding with TiO_2 nanofluid. As conclusion, TiO_2 nanofluid exhibits the better grinding surface quality. For recommendation, various machining can be conducted using nanofluid to emphasize better results.

ABSTRAK

Kekasaran permukaan adalah pembolehubah yang sering digunakan untuk menggambarkan kualiti permukaan pengisaran serta menilai daya saing keseluruhan sistem pengisaran. Satu proses pengisaran dilakukan ke atas P20 tool steel dengan menukar syarat-syarat pengisaran, termasuk kedalaman potongan, pas pengisaran, jenis roda, dan bekalan bendalir pemotongan dalam eksperimen. Objektif utama kajian ini adalah untuk mengkaji kesan TiO_2 nanofluid pada kualiti permukaan pengisaran dan hayat roda pengisaran. 0.1% kepekatan TiO_2 nanofluid disediakan untuk membandingkan keberkesanan dengan water based coolant. Enam Spesimen dipilih menjalani SEM untuk menilai integriti permukaan pemesinan. Model ramalan ANN dihasilkan dari data yang dikumpul. Keputusan eksperimen menunjukkan pengurangan 20% kepada 40% nilai kekasaran permukaan dalam penggunaan TiO_2 nanofluid. Sebagai kesimpulan, TiO_2 nanofluid mempamerkan pengisaran permukaan yang berkualiti. Percadangan selanjutnya adalah penggunaan nanofluid boleh dijalankan dalam pelbagai pemesinan untuk menekankan keputusan yang lebih baik.

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LIST OF SYMBOLS

F_n	Normal grinding force
F_t	Tangential grinding force
Ra	Arithmetic average surface roughness
rpm	Revolution per minute
$wt\%$	Weight percentage
V	Volume
v_s	Work table speed
v_w	Grinding wheel speed
$\%$	Percentage
φ	Weight percentage
ρ	Density in kg/m^3
$\emptyset$	Volume percentage

LIST OF ABBREVIATIONS

AISI	American Iron and Steel Institute
Al_2O_3	Aluminium Oxide
ANN	Artificial Neural Network
C	Carbon
CNTs	Carbon Nanotubes
Cr	Chromium
Cu	Copper
DOC	Depth of Cut
Exp.	Experimental
EVO	Evolution
Fe	Iron
Mn	Manganese
Mo	Molybdenum
MSE	Mean Square Error
MQL	Minimum Quantity Lubricant
Ni	Nickel
P	Phosphorus
S	Sulphur
SEM	Scanning Electron Microscopy
Si	Silicon
SiC	Silicon Carbide
SiO_2	Silicon Dioxide
TiO_2	Anatase or Titanium Dioxide

TRN	Training
TST	Testing
VLD	Validation
UMP	University Malaysia Pahang

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Grinding is a material removal and surface generation process used to shape and finish components made of metals and other materials. It is one of the abrasive machining that always to achieve high enough dimensional accuracy and/or good quality surface finishes. Grinding is a manufacturing process with unsteady process behaviour, whose complex characteristics determine the technological output and quality. The quality of the surface generated by grinding determines many work piece characteristics such as the minimum tolerances, the lubrication effectiveness and the component life, among others. The grinding parameters can help to improve the wheel life and the quality of the work piece. The suitable grinding parameters can save cost, time, energy and get the good quality for surface condition. (Aguair et al., 2008)

In the past few decades, rapid advances in nanotechnology have led to emerging of new generation of coolants called “nanofluids”. Nanofluids are dilute suspensions of functionalized nanoparticles composite materials developed about a decade ago with the specific aim of increasing the thermal conductivity of heat transfer fluids, which have now evolved into a promising nanotechnological area. The enhanced thermal behaviour of nanofluids could provide a basis for an enormous innovation for heat transfer intensification, which is of major importance to grinding process as higher stock removal rates, higher quality, and longer wheel life are sought.

1.2 PROBLEMS STATEMENT

Tool steel refers to a variety of carbon and alloy steels that are particularly well-suited to be made into tools for cutting, forming, or other types of metal-working applications. Tool steels are often subjected to surface grinding. The wide differences in composition among tool steels give rise to wide variations in grinding characteristics. The P20, kind of low carbon tool steel containing chromium and molybdenum alloying elements, to fill the requirements for the machined cavities and forces used in zinc die casting and plastic molding. Hence the grinding of P20 tool steel requires high quality of surface finish. The optimum grinding parameters are crucial in pursuit of better surface finish.

Grinding process requires high energy expenditure per unit volume of material removed. Virtually all of this energy is dissipated as heat at the grinding zone where the wheel interacts with the work piece. This leads to the generation of high temperatures which can cause various types of thermal damage to the work piece. Thermal damage is one of the main factors which affects work piece quality and limits the production rates which can be achieved by grinding. Therefore, cooling and lubrication play a decisive role in grinding as to enhance process stability, better work piece quality and tool life.

1.3 PROJECT OBJECTIVES

The objective of the study is to determine the effect of TiO_2 nanofluid on the grinding surface finish and wheel wear. Secondly, is to determine the effect of the variation axial depth on the grinding surface quality. Moreover, is to investigate the influence of the grinding passes to the surface quality. Lastly, the objective is to develop artificial intelligence models using Neural Networks.

1.4 PROJECT SCOPES

The work piece used for the study is AISI P20 tool steel. The total number of grinding experiments is 54 sets of experiment. There will be 36 set experiments for grinding using water based coolant and the remains is using TiO_2 nanofluid as cutting fluid. The conducted grinding process will be single pass and multi passes grinding. The multi passes grinding is set to be 4 passes. The grinding wheel for the experiment will be Al_2O_3 grinding wheel and SiC grinding wheel. The only manipulated grinding parameter is depth of cut. The range of depth of cut is within 5 µm to 21 µm. The work table speed, v_s and grinding wheel speed, v_w are held constant throughout the experiments which are 20 m/min and 2850 rpm respectively. The water based coolant use comprises the composition of ethylene glycol and water with ratio of 6:4. The wheel and dressing conditions used for the model calibration and validation are the same for each experiment. The effect of concentration of the nanofluid is not considered in the study. Batch back propagation is used for Artificial Neural Network modelling training algorithm.

1.5 THESIS OUTLINED

This thesis consists of 5 chapters which illustrate the system design of the project. Every chapter presented with different contents. After viewing the entire chapter in the thesis hopefully viewer may conceive the system design of the project.

Chapter 1 contains of the project background, the problem statement of the project, the objectives of the project, the scopes of the project and the outline of the thesis for every chapter.

Chapter 2 contains all the literature review. This chapter will explain the information about the article that related to the project that is done by other research. This chapter also describes the journals and others important information regarding this project.

Chapter 3 is chapter for the methodology of the project. This chapter will explain about the detail of the project. It's also includes the project progress presented in flow chart and also the explanation in detail about the project.

Chapter 4 discusses the result and the analysis for this project. This chapter will explain on the results and analysis of the project. The analysis includes the comparable results between grinding experiments using water based coolant and nanofluid. Both values will be compared to justify the theory. The Artificial Neural Networks modelling prediction models of the grinding experiments are discussed.

Chapter 5 will explain the conclusion of the project. It's also includes the future recommendation of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the finding and previous study regarding grinding machinability were reviewed. This chapter will present about the influence of grinding parameter on the surface quality and the tool wear. On the other hand, some concept which related to the grinding included the mechanics of chip formation and during grinding and grinding thermal effect also will be discussed in this chapter. The significant of the cutting fluid also included in the chapter. The introduction and cooling application of nanofluid are elucidating in the chapter. Besides that, this chapter also will explain about the history background and presentation of the earlier work undertaken of this study. By referring to the history background and presentation of the earlier work undertaken of this study, the expected output can be predicted. The expected output based on the previous study can be used in the result and discussion in order to justify or compared the result obtained.

2.2 GRINDING

Grinding is the finishing machining operation to ensure the final surface quality. During the grinding process, small chips are removed along with high rates of material removal. Since grinding is mostly used as finishing method, which determines the functional properties of the surface, the knowledge of the surface quality and its control are crucial. It is therefore an effort to achieve high levels of surface quality, conditionally improved by the grinding process, choosing the appropriate cutting conditions.

The quality of grinded surface is generally defined as the sum of the properties under consideration upon demands. The resulting surface quality depends on input factors such as principally cutting conditions are, followed by grinding material and accompanying phenomena. Surface quality includes physical, chemical and geometric properties. The geometric surface properties include roughness parameters as a characteristic of micro geometry in the cut plane perpendicular to the surface. (Samek et al., 2011)

2.2.1 Surface Grinding

Surface-grinding processes are classified in Germany according to DIN 8589-11 in terms of the predominantly active grinding wheel surface position and of the table feed motion type. In the case of peripheral grinding, the grinding spindle is parallel to the work piece surface to be machined. The work piece material is mainly cut with the circumferential surface of the grinding wheel.

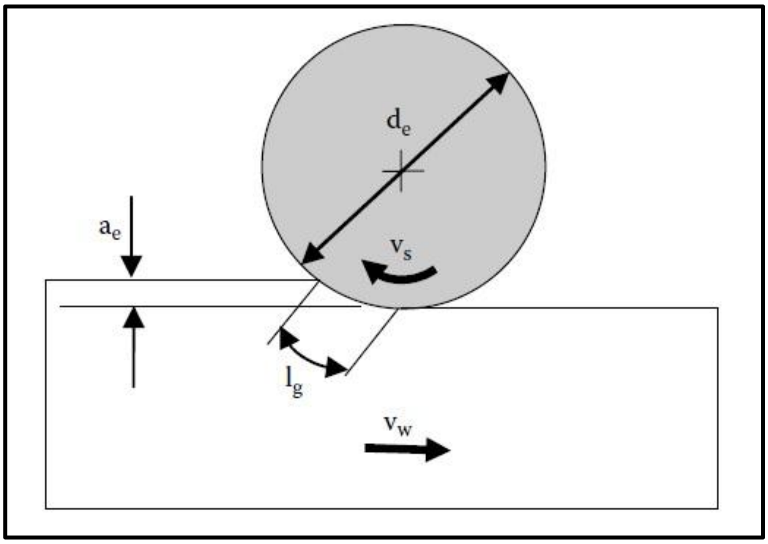

Figure 2.1: Wheel speed, work speed, depth of cut, equivalent grinding wheel diameter, and geometric contact length in grinding

Source: Marinescu et al. (2007)

2.2.2 Real Depth of Cut

The real depth of cut, a_e is the feed relative to the work piece surface. It is important to recognize that the real depth of cut is not the same as the set depth of cut. This is due to deflections of the grinding wheel, of the machine, and due to wheel wear. Grinding performance should always be related to the real depth of cut, otherwise the results will depend very strongly on the particular grinding wheel and the particular grinding machine setup.

2.2.3 Surface Roughness

Every machining operation leaves characteristic evidence on the machined surface. The quality of machined surface is characteristics by the accuracy of manufacture with respect to the dimensions specified by the designer. Surface roughness is a variable often used to describe the quality of ground surfaces and also to evaluate the competitiveness of the overall grinding system. Surface roughness is one of the most important features of a machining process because it affects the functions of the part. In a grinding process, it is very important to keep the surface roughness within specified requirements because this process is the final machining process which usually at the last stage of the machining. (Agarwal and Rao, 2007)

According to Marinescu et al. (2006), the ability of manufacturing operation is based on many factors. The final surface depends on the rotational speed of the wheel, work speed, feed rate, types of work piece being machined, depth of cut, diameter of work piece, types of wheel, and others parameter that can effect to the surface finish of the work piece. Type and amounts of lubricant use for grinding process also influence the surface roughness. Different types of machine have different variable parameters that can be change to get the best surface finish. Kalpakjian and Schmid (2006) explain about regardless of the method of the production, all surfaces have their own characteristics which collectively are referred to as surface structure. As a geometrical property is complex, certain guide lines have been established for texture in terms of well-defined and measurable quantities.

On this study, the surface roughness of the grounded area of the work piece is measured by *Ra* roughness. *Ra* roughness is the arithmetic average of all profile ordinates from a mean line within a sampling length after filtering out form deviations. (Marinescu et al., 2006)

The magnitude of the roughness is influenced by the hardness of the material ground as well as the elastic properties of the work piece, grit and binder materials. The elastic deflection of the grit at contact is generally found to be small. A grinding wheel has roughness in the axial and circumferential directions. The grinding grits flake, chip and fracture as well as is pulled out of the binder. Furthermore, when materials lying to high adhesion are ground the grit is capped by adherent lumps. The roughness of the wheel therefore changes continuously with the length and the number of passes.

2.2.4 Grinding Force

Grinding force is one of the most important parameters in evaluating the whole process of grinding. Generally, the grinding force is resolved into three component forces, namely, normal grinding force *F*n, tangential grinding force *F*t and a component force acting along the direction of longitudinal feed which is usually neglected because of its insignificance. The normal grinding force *F*n has an influence upon the surface deformation and roughness of the work piece, while the tangential grinding force *F*t mainly affects the power consumption and service life of the grinding wheel. The force plays an important role in grinding process since it is an important quantitative indicator to characterize the mode of material removal (the specific grinding energy and the surface damage are strongly dependent on the grinding force). (Agarwal and Rao, 2007)

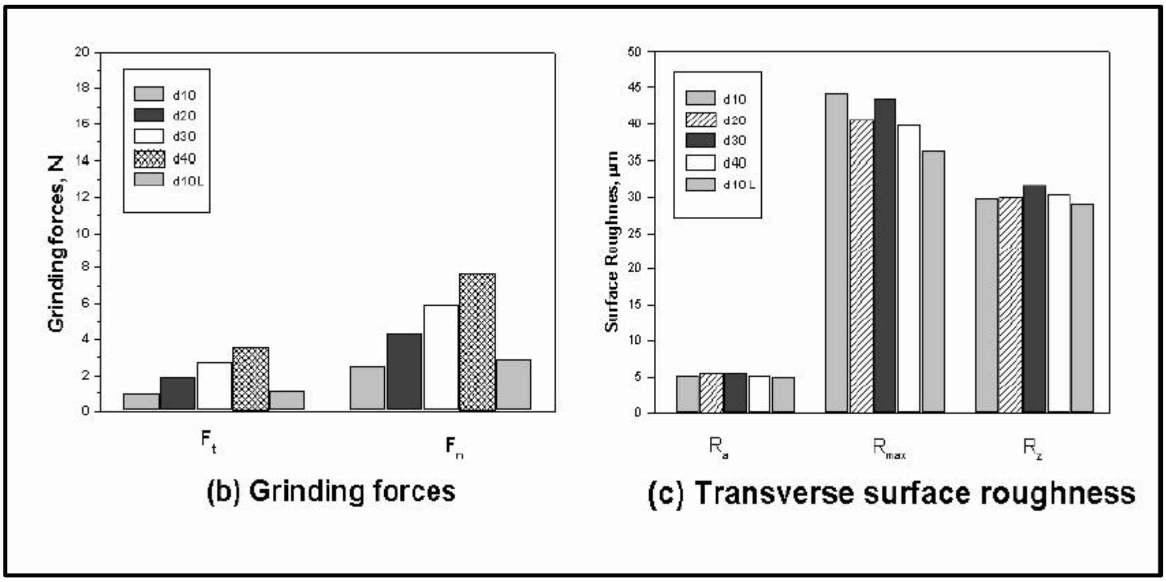

Figure 2.2: (b) Grinding forces vs depth of cut; (c)Transverse surface roughness vs depth of cut

Source: Agarwal and Rao (2007)

Grinding parameters like grinding velocity, traverse speed or wheel depth of cut affects the grinding force which in turn can cause fracture, rounding or flattening on few overlying grits thus, bringing more number of underlying grits into action. This change in topographical feature of single layer wheel, in various levels, affects the surface roughness of the work piece. Grinding force increases with decrease in grinding velocity while the same increases with increase in table speed and depth of cut. Accordingly a trend is observed on decrease of surface roughness with decrease in grinding velocity and increase of both traverse speed and wheel depth of cut.

Grinding forces not only affect chip formation mechanics, grain wear and temperature distribution but also efficiency of the grinding operation. Therefore, grinding forces are among the most important factors affecting grinding quality. (Demir et al., 2010)

2.3 MECHANICS OF CHIP FORMATION DURING GRINDING

For grinding of a work piece surface, ideal cutting can be obtained by many process combinations like ploughing due to lateral displacement, work piece movement, grinding wheel movement, elasticity of the work piece and vibration. (Midha et al., 1991)

Kinematic relation between grinding wheel and work piece in grinding process is applied to each grain of the grinding wheel. Some faces of grain during grinding can be illustrated the geometrical relation between a single grain and work piece. Non-deformed chip shape, tool path length of the abrasive grain (lk), maximum non deformed depth of cut (hm) and chip geometry are shown schematically in Figure 2.2.

Chip formation in grinding process can be divided into three successive stages: friction, ploughing and cutting. In up-cut grinding, grinding wheel grains rub on the work piece surface rather than cutting due to the elastic deformation of the system. This is called friction stage. And then, plastic deformation takes place as the elastic limit is exceeded between the abrasive grain and work piece. This is called ploughing stage. Work piece material flows plastically through forward and sideward ahead of the abrasive grain and forms a groove. When the work piece material cannot resist the flow stress, chip is formed. The chip formation is called cutting stage. In this chip formation stage, energy is used most efficiently. Rubbing and ploughing are inefficient, since the energy is wasted in deformation and friction with negligible contribution to material removal. Furthermore a high temperature may result, producing an excessive rate of wheel wear and the work piece surface may suffer metallurgical damage. (Chen and Rowe, 1995)